Before the
FEDERAL COMMUNICATIONS COMMISSION
Washington, DC 20554

In the Matter of Amendment of the Commission's Rules with Regard to Commercial Operations in the 3550-3650 MHz Band	GN Docket No. 12-354

COMMENTS OF QUALCOMM INCORPORATED

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SUMMARY

Qualcomm is very excited by the Commission's proposal to enable deployment of small cells in the 3.5 GHz band using Authorized Shared Access ("ASA"), a licensed regulatory framework that can offer mobile operators and their subscribers exclusive access to this under-utilized band where and when U.S. government incumbents are not using it. Qualcomm originally proposed this framework to the FCC more than two years ago, and Qualcomm and its industry partners — including European operators, vendors, and even regulators — are working to standardize ASA in ETSI.

The FCC aptly notes in the *3.5 GHz Small Cells NPRM* that the U.S. is in the midst of a spectrum crunch due to the seemingly never-ending surge in demand for mobile broadband data. To quantify the challenge at hand, Qualcomm has set the goal of expanding wireless network capacity by 1000 times to meet this exploding demand. To do so will require the parallel development and deployment of new network architectures and technologies, massive capital expenditures by the wireless industry, and allocation of far more mobile broadband spectrum. Indeed, Qualcomm and its partners are laser-focused on putting each available sliver of spectrum to its highest and best use to expand capacity as much as possible.

The new spectrum must include bands that can be completely cleared of incumbents, auctioned, and brought on line in a reasonable time frame and by a date certain — such as the 600 MHz band that is being repurposed via the incentive auction process. New spectrum will also include more unlicensed spectrum that can support offloading from licensed bands in situations where a more reliable quality of service and full mobility may not be necessary and where there is wider bandwidth to support greater capacity and higher data rates such as in the 5 GHz band using 802.11ac in channels of up to 160 MHz of contiguous spectrum and in the 60 GHz band in channels as wide as 2 GHz. But, simply relying on those two sources of

spectrum will leave off limits a third type of spectrum that is not allocated for mobile broadband, but is under-utilized. The 3.5 GHz band falls into this third category. As a nation, we should not put such spectrum off limits for mobile broadband because it is under-utilized, even though it apparently cannot be cleared of incumbents in a reasonable time frame and by a date certain. Despite the limitations on the spectrum because of its use by the government incumbents, it can nevertheless be integrated into carrier networks to support full mobility and provide a reliable quality of service where and when the incumbents are not using it. By using ASA to enable the 3.5 GHz band to be shared by small cells, mobile network capacity can be expanded significantly for American consumers.

There is no question that our first choice for additional spectrum for mobile broadband remains fully cleared spectrum. However, the 3.5 GHz band apparently cannot be cleared of U.S. government incumbents on a nationwide, 24/7 basis by a date certain in a reasonable time frame, but the band is far from fully occupied. Given these circumstances and the pressing need for additional mobile broadband spectrum, there needs to be a technical / regulatory paradigm that enables this band to be utilized fully and with a predictable quality of service. ASA is that paradigm. ASA allows commercial licensees to operate within the interstices of the frequency band whenever and wherever government users are not using it, and to move off of the spectrum quickly when and where incumbents need to operate. ASA can unlock this band from coast to coast where and when it can be made available for mobile broadband and also prevent interference to and from the incumbents.

Qualcomm greatly appreciates the Commission's favorable presentation of ASA in the *3.5 GHz Small Cells NPRM,* and, in particular, the agency's recognition that small cells, when deployed in conjunction with an existing mobile broadband network, can dramatically increase network capacity. Indeed, Qualcomm believes that the establishment of a dedicated band for small cells at 3.5 GHz is an important piece of the FCC's multi-faceted efforts to make much-needed mobile broadband spectrum available.

The *3.5 GHz Small Cells NPRM*, relying upon the NTIA Fast Track Report, explains that the band is under-utilized but cannot be cleared of incumbent federal users, particularly Naval radar systems, on a nationwide, 24/7 basis in a timely manner. Based upon its belief that the spectrum would be used for a macro-cellular network, NTIA proposed enormous exclusion zones that stretched inland for hundreds of miles and covered 60% of the U.S. population. The band would not be viable with those limitations, as the FCC recognizes in the *NPRM*.

Qualcomm's analysis, as detailed in these Comments, shows that if the 3.5 GHz band is used for small cells operating at substantially lower power levels on a licensed and tightly-managed basis via the ASA framework, interference to radars can be avoided and the required exclusion zones drastically reduced. Small cells, when incorporated into existing macro cellular networks operating in other bands, would greatly expand mobile broadband network capacity, bringing some relief to the mobile broadband capacity crunch. While allowing the 3.5 GHz band to be shared by small cells will shrink the exclusion zones substantially and help ease the spectrum crunch, there will be times and locations when the small cells will not be able to use the spectrum because the government incumbents will be using the spectrum. At those times and locations, the small cells will move to another portion of the 3.5 GHz band, or to another band, using the same multi-band support and frequency agility that today's macro and small cells utilize. ASA enables state-of-the-art mobile cellular broadband technology, including self organizing networks and advanced interference management/mitigation techniques.

By providing a secure interface between federal users and ASA rights holders, the ASA framework will protect sensitive information, such as when and where Naval radars are operating. At its core, ASA is a binary system; the ASA spectrum rights holder has an exclusive right to use a given portion of the spectrum when and where it is not used by federal incumbents. At any given location and at any given time, a specific channel in the spectrum will be used either by the federal incumbent or a single ASA rights holder. ASA rights must be exclusive in order to support the delivery of a reliable and predictable quality of service while guaranteeing interference-free spectrum sharing between incumbent systems and the ASA rights holders' networks. Making ASA rights exclusive will prevent interference between the small cells and radars. These exclusive rights may be awarded by geographic area (similar to licenses awarded today via auction) or in some other manner (such as a licensed-by-rule framework), or both perhaps, each in discrete portions of the bands — as contemplated in the *NPRM*. In other words, the mode of licensing could be carrier-driven, consumer-driven, or a combination of the two.

It is particularly important to highlight that ASA is completely transparent to the end user device. Operation within the ASA framework does not require any changes to the device or the underlying cellular technology. Indeed, from the device's perspective, operating on 3.5 GHz under ASA would not be any different from operating on any other band, whether there are macro cells and/or small cells on that band. ASA uses a database to which the ASA rights holder's Operations, Administration, and Maintenance ("OAM") network system would connect to determine the interference limits within which the ASA licensee can operate within a particular channel at a given time and location. The ASA database needs to know the aggregate power level that U.S. government incumbents can tolerate at a given location, time, and frequency. The ASA database thus provides all the information needed to ensure that that power level is not exceeded at that location, time and frequency. Once a small cell is cleared for communications by the ASA licensee, operation occurs within the small cell service area just as it would within a macro-cell, even enabling the spectrum to be used for carrier aggregation or supplemental downlink to achieve the best possible user experience.

Licensed spectrum sharing once may have sounded highly academic and theoretical, and perhaps that is still the case for some variants of the concept. With ASA, however, that is not the case. The system requirements, such as how the network OAM will interface with the ASA database, are being standardized in ETSI. In deciding how to best move forward with small cells in the 3.5 GHz band, the FCC should take advantage of ETSI's work on ASA.

In sum, Qualcomm and others in the industry have done a great deal of work developing, testing, and standardizing ASA technology, and, for sure, there are still practical challenges to be overcome. Nevertheless, as a leading wireless technology provider that is developing and field-testing small cells, Qualcomm is excited about the deployment of small cells at 3.5 GHz using ASA and looks forward to continuing to work with all stakeholders to ensure that this goal is reached as soon as possible.

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COMMENTS OF QUALCOMM INCORPORATED

QUALCOMM Incorporated ("Qualcomm") is pleased to comment on the Commission's *3.5 GHz Small Cells Notice of Proposed Rulemaking*, which formally begins the process of introducing, into the U.S. mobile ecosystem, small cell deployments in the 3550 to 3700 MHz band on a licensed shared basis with federal incumbent operators.[1] Qualcomm is particularly pleased with the FCC's proposal to use, in accordance with small cell deployments, the Authorized Shared Access ("ASA") licensed regulatory framework that Qualcomm first proposed to the FCC more than two years ago, and Qualcomm and its wireless industry partners, operators, vendors, and regulators, are standardizing in ETSI.[2]

The ASA framework allows mobile broadband operators to gain exclusive access to under-utilized spectrum that is allocated to federal operations on a primary basis when and where the primary federal users are not active. The 3.5 GHz band apparently cannot be completely cleared of U.S. government incumbents on a nationwide basis by a date certain within a

1 *See* Amendment of the Commission's Rules with Regard to Commercial Operations in the 3550- 3650 MHz Band, GN Docket No. 12-354, *Notice of Proposed Rulemaking and Order*, FCC 12-148 (rel. Dec. 12, 2012) ("*3.5 GHz Small Cells NPRM*" or "*NPRM*") at ¶¶ 1-6.

2 *See id*. at ¶ 84 (seeking comment on the two-tiered ASA model).

reasonable time frame, and ASA allows commercial licensees to operate within the interstices of the frequency band whenever and wherever government users are not. The ASA framework also facilitates commercial users quickly moving off of the spectrum when incumbents need to operate. In this way, ASA licensees can offer a predictable quality and service, including falling back to other bands if needed, and federal users can retain access without interfering with ASA licensees and vice versa.

As a leading developer of mobile broadband technologies and chipsets that are fueling the mobile broadband revolution, Qualcomm's comments aim to provide technical input to assist the Commission in developing the ASA regulatory paradigm, which, as described herein, is a relatively simple, two-tier spectrum access system that will allow small cell technology to flourish at 3.5 GHz. Qualcomm has studied the NTIA Fast Track Report, which identified the 3.5 GHz band for potential use as broadband spectrum,[3] and has found that if lower-power small cell technology are used in the exclusion zones proposed by NTIA, the exclusion zones can be reduced substantially from the sizes originally recommended by NTIA — that is, from hundreds of miles inland to tens of miles inland — and also enable substantial capacity gains through network densification where it is needed, that is, in the most densely populated regions of our country.[4] In this way, 3.5 GHz band operations enabled via ASA could can take place within the

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3 *See* NTIA, An Assessment of the Near-Term Viability of Accommodating Wireless Broadband Systems in the 1675-1710 MHz, 1755-1780 MHz, 3500-3650 MHz, 4200-4220 MHz, and 4380-4400 MHz Bands (rel. Oct. 2010) ("NTIA Fast Track Report"); *see also* FCC Public Notice, DA 11-444, Spectrum Task Force Requests Information On Frequency Bands Identified By NTIA As Potential Broadband Spectrum, ET Docket No. 10-123 (Mar. 8, 2011) (seeking input on use of the bands identified by NTIA for mobile broadband: 1695-1710 MHz, 1755-1780 MHz, 3550-3650 MHz, 4200-4220 MHz, and 4380-4400 MHz).

4 *See 3.5 GHz Small Cells NPRM* at ¶ 2 n.4 & ¶ 14 n.19 (citing Qualcomm 1000X Data Challenge presentation and Nokia Siemens Networks Beyond 4G Radio Evolution to Gigabit Experience paper).

NTIA exclusion zones, in fact, right up to the coastline, and thus complement mobile operators' existing networks in areas of the U.S. that are among the most capacity constrained.

In addition, Qualcomm has built and field tested small cell deployments, and it has shown that adequate coverage can be provided with a relatively low penetration of small cells. The circuit board for one of Qualcomm's small cell prototypes is shown in Figure 1 below.

Figure 1. Qualcomm's Prototype Small Cell

These small cells will be far cheaper, less obtrusive, and considerably easier to install than traditional base station towers.[5] The largest component on this prototype small cell is the Ethernet jack, which could be used for backhaul. Small cells also can use wireless backhaul, where it is available. Thus, we envision small cells that could take the form of a dongle-type device, or be integrated into a router, cable modem, or set-top box.

5 *See* Ariel Bleicher, *A Surge in Small Cell Sites*, IEEE SPECTRUM (Jan. 2013).

Qualcomm's analysis of the 3.5 GHz band is ongoing, and before Qualcomm can further refine its analysis, additional information on the technical and usage characteristics of the incumbent federal operations is needed, particularly the airborne, shipborne and ground-based federal radar systems. We look forward to integrating this information into our analyses and subsequent proposals of how best to make use of this spectrum within the zones that could be affected by federal incumbent users.

DISCUSSION

I. Qualcomm Strongly Supports The Commission's Proposals To Enable The Licensing Of Small Cells At 3.5 GHz Using Authorized Shared Access Technology

Qualcomm agrees with the Commission that the 3.5 GHz band is a perfect place to deploy small cell technology that uses a geo-location-enabled database to ensure successful spectrum sharing between incumbent federal government entities and mobile broadband licensees, who would gain exclusive access to the spectrum where and when the federal government is not using it.[6] Also, Qualcomm wholeheartedly supports FCC implementation of the two-tiered ASA framework at 3.5 GHz, for the reasons set forth below.

ASA, which Qualcomm first described two years ago in multiple FCC filings,[7] is a secure, licensed spectrum sharing framework that uses such a database or Spectrum Access System ("SAS"). The ASA regulatory framework ensures that spectrum use is made more

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6 *See, e.g., 3.5 GHz Small Cells NPRM* at ¶¶ 6, 21.

7 *See* Comments of Qualcomm, Inc., at i, 2-3 & 5-10 in ET Docket No. 10-237, *Promoting More Efficient Use of Spectrum Through Dynamic Spectrum Use Technologies* (Feb. 28, 2011) (touting also the benefits of heterogeneous networks and small cells); Comments of Qualcomm, Inc., at i & 4-9, in ET Docket No. 10-123, *Spectrum Task Force Request For Information On Frequency Bands Identified By NTIA As Potential Broadband Spectrum* (Apr. 22, 2011). *See also* Comments of Qualcomm, Inc., at 5-6, in ET Docket No. 10-236, *Promoting Expanded Opportunities for Radio Experimentation and Market Trials under Part 5 of the Commission's Rules and Streamlining Other Related* Rules (Mar. 10, 2011).

efficient by allowing much-needed mobile broadband spectrum to be made available in a timely manner. ASA can adapt to market demand and maximize value to consumers by supporting the release of additional spectrum, sooner rather than later, so new wireless broadband business models can thrive.

A. ASA Is A Two-Tiered Licensed Spectrum Sharing Framework That Permits Mobile Broadband Connectivity Where and When Incumbent Government Users Are Not Operating

Spectrum management in the U.S. and around the world is based principally on the separation of users by frequency band. As the *3.5 GHz Small Cells NPRM* notes, a large amount of spectrum is reserved for the U.S. government, but at least some of that spectrum is not fully utilized by these federal incumbents on a 24/7, nationwide basis.[8]

At the same time, mobile broadband network operators are increasingly constrained by the difficulties involved in gaining access to the additional spectrum needed to support end users' skyrocketing data demands while providing a consistent quality of service. ASA offers an improved means of sharing spectrum with incumbent users via a two-tiered licensed sharing framework. It provides a straightforward means of improving spectrum utilization, as it opens partially-occupied spectrum for mobile broadband use while fully protecting incumbent operations that continue operating in the band. ASA also provides tools to allow ASA licensees and incumbent federal users to work cooperatively to meet demand spikes.

As explained below, with regard to the 3.5 GHz band in particular, the ASA regulatory framework can incorporate the necessary "geographic restrictions to protect existing Department

8 *See 3.5 GHz Small Cells NPRM* at ¶ 6 (identifying 3.5 GHz as the "ideal band in which to propose small cell deployments and shared spectrum use"; noting that the incumbent uses in the band include high powered Department of Defense radars, non-federal Fixed Satellite Service ("FSS") earth stations for receive-only, space-to-earth operations and feeder links, and that the adjacent band below 3550 MHz contains high-powered ground and airborne military radars).

of Defense ("DoD") radar and FSS operations and to protect new commercial systems from co-channel interference from high-powered military in-band shipborne and adjacent band DoD ground-based radar systems."[9]

There are three distinct means by which an ASA licensee can share spectrum with an incumbent, each of which will play a role at 3.5 GHz: (i) by geography or location. (ii) via time sharing, and (iii) via frequency band usage sharing. Each of these approaches can work either by itself or in conjunction with one or both of the others

Geographic or Location Sharing. When a primary federal incumbent user operates in certain geographic areas, it is possible for the ASA license holder to use the spectrum in other geographic areas, respecting necessary exclusion zones defined to protect primary operations. The ASA regulatory framework can adapt easily as the geographical availability of ASA spectrum evolves over time, and potentially increases as incumbents move to more confined geographic areas or transition out of the band.

Time Sharing. Federal incumbent users that use the spectrum at certain times open the possibility for ASA licensees to use the spectrum at other times. Such an implementation obviously works best where primary operations are occasional.

Frequency Band Usage Sharing. While a primary user currently may hold an allocation to operate across the entirety of the 3.5 GHz frequency band, it may only use a portion of the band at a given place or point in time, which opens the possibility of providing ASA licensees' access to the unused portions of the frequency band.

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9 *See 3.5 GHz Small Cells NPRM* at ¶ 18 (explaining that the 3.5 GHz radar systems overcome the inherent limitations due to increased propagation losses by using high transmitter power levels and high-gain antennas, and noting that these characteristics contributed to the size of the exclusion zones in NTIA's Fast Track evaluation).

Database or Spectrum Access System. To support one or some combination of the above sharing means, ASA-enabled networks would communicate with a database. In the case of small cells operating in the 3.5 GHz band, the network operator's Operations, Administration, and Maintenance ("OAM") system would connect to an ASA database, or Spectrum Access System ("SAS")[10] as the *NPRM* refers to it, that would provide information about the available spectrum to ASA network operators so they could manage their spectrum use. The ASA controller would store information about exclusion zones necessary to protect primary incumbent systems in various portions of the 3.5 GHz band. Specifically, the ASA controller would be informed by the government incumbents how much interference power they can tolerate at a given location, at a given point in time, on a given frequency, and thus provide dynamic, real-time information on the ASA licensee's ability to use spectrum within an exclusion zone.

The logical architecture of an ASA-enabled system is shown in Figure 2 below. The ASA Controller needs to know the power level that the incumbent can tolerate within a particular channel at a particular location and time. It then will use that information to determine the availability of spectrum in a given location, within a particular channel, and at a particular time, based on information it also receives from the known mobile network seeking to operate at that same location. It will ensure that mobile broadband communications only occur on an interference-free basis. This information is fed to the operator's Operations, Administration and Maintenance ("OAM") system, which is essentially equivalent to the OA&M system used in today's mobile broadband networks.

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10 *See, e.g., 3.5 GHz Small Cells NPRM* at ¶ 7. Future implementations of ASA may possibly be augmented by using spectrum sensing techniques, but Qualcomm is not proposing such operations at this time because a great deal more research, development, and analysis work is needed.

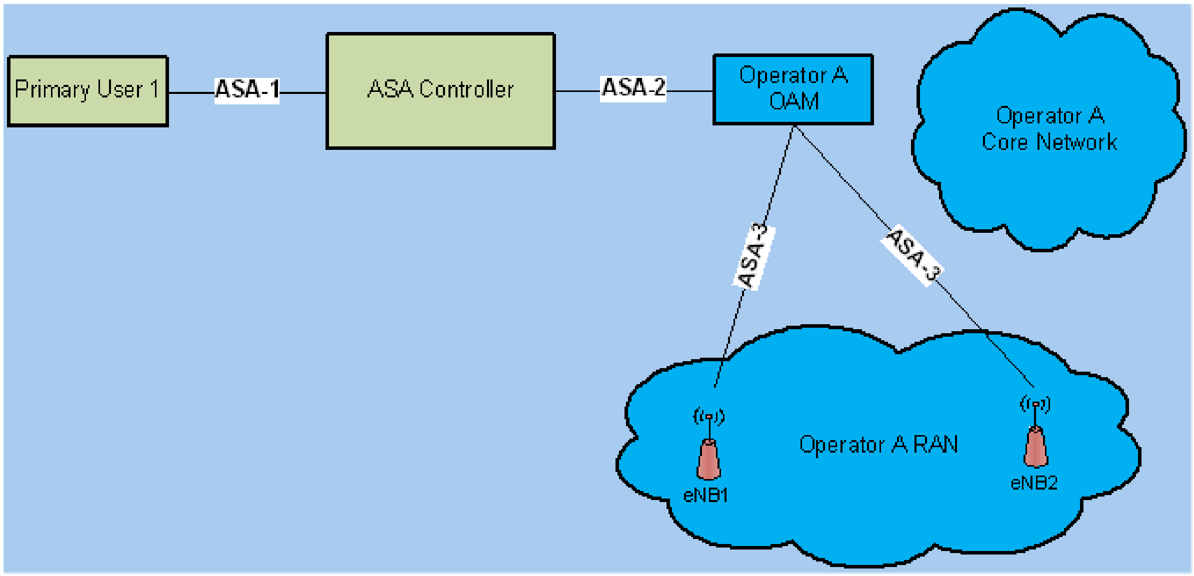

Figure 2. Logical Architecture of the ASA Network

In the ASA framework, the OAM system manages the ASA licensed spectrum, by translating into Radio Resource Management commands the information on spectrum availability obtained from the ASA Controller. These commands are then transmitted to small cell base stations (*e.g.*, eNB1 and eNB2) in the operator's Radio Access Network ("RAN"). Based on this information, the small cell base stations enable user devices to access the ASA spectrum or order them to hand off seamlessly to other frequency bands as appropriate, subject to ASA spectrum availability, Quality of Service ("QoS") requirements, data rates, and data plans. If necessary, the OAM commands the base stations to tune to different channels or power down. A user device located in the area where the ASA band is available, such as eNB1, can access either the underlying licensed band and the ASA band (or both bands if it has the appropriate carrier aggregation capabilities). A user device located in an area where the ASA band is temporarily unavailable, say, for example, near eNB2, may only have access to the underlying licensed band. In this way, the ASA model prevents interference to the incumbent users and manages access to the spectrum to ensure successful spectrum sharing with incumbent users and other mobile users.

B. ASA Can Be Deployed Quickly And Reliably Since It Is Designed To Fully Protect And Successfully Share Spectrum With Federal Incumbents

By taking full advantage of elements within the mobile operator's network, ASA can be deployed quickly and reliably. Moreover, as explained above, ASA is designed to provide full protection of incumbent operators, in accordance with the FCC's goals.[11] At its core, ASA is a binary system in which the spectrum is used at a given location either by the primary incumbent or by the ASA rights holder, which has an exclusive right to use the spectrum at the times, locations, and frequencies that are not being used by federal incumbents. In this way, ASA allows federal incumbent users to coexist with ASA licensees on a long-term basis as well as on a rolling basis while incumbent users transition to another band.

ASA rights must be exclusive in order to support the delivery of a reliable and predictable quality of service while guaranteeing interference-free spectrum sharing between the government systems and the ASA rights holders' networks. These exclusive rights may be awarded by geographic area (similar to licenses awarded today via auction), or in some other manner (such as licensed-by-rule), or both perhaps each in discrete portions of the bands — as the Commission sets out in the *3.5 Small Cells NPRM*.[12]

ASA, with its binary framework, can enable operations at 3.5 GHz without having to implement the multi-tiered structure that the FCC envisions in the *NPRM*.[13] A geographic area licensee would be able to deploy small cells throughout its network and service any and all types of mobile broadband devices. And, were the FCC to implement a licensed-by-rule approach in a

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11 *See 3.5 GHz Small Cells NPRM* at ¶ 65 ("ultimate success of shared use of the 3.5 GHz Band depends on providing wide ranging commercial access to the band … while ensuring that current users of the band continue to be protected from harmful interference").

12 *See id.* at ¶ 11.

13 *See id.* at ¶¶ 64-76 (seeking input on a three-tiered licensing framework).

portion of the band, the ASA framework would enable two nearby small cells to dynamically adjust their power levels and possibly operate in different parts of the band to provide a consistent and reliable quality of service. Thus, ASA is compatible with any number of licensing models with its simple mode of enabling interference free communications for all types of licensed mobile broadband users.[14]

It is particularly important to highlight that ASA is completely transparent to the end user device. Indeed, operation within the ASA framework does not require any changes to the device or underlying cellular technology. From the device's perspective, enabling operations at 3.5 GHz under ASA is no different from adding support for a new band in a macro-cellular network.

As shown in Figure 2 and explained above, ASA uses a database to which the ASA rights holder's OAM system connects to determine if a particular small cell base station can use the spectrum within a particular channel at a given time and location. The ASA database needs to know the aggregate power level that U.S. government incumbents can tolerate at a given location, time, and frequency.[15] Using this information, ASA database can thus ensure that that power level is not exceeded at the given location, time, and frequency. Once the small cell is cleared for communications, operation occurs within the small cell service area like it would within a macro-cell. In this case, the available spectrum can be used by a carrier to implement carrier aggregation, as noted above, or supplemental downlink.

It also is important to note that if an incumbent federal user suspects interference, the ASA licensee is readily identifiable should remediation efforts be necessary. Once the FCC permits the deployment of small cells at 3.5 GHz using ASA, and federal users become

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14 *See id.* at ¶ 84.

15 *See id.* at ¶¶ 95, 97.

comfortable with the capabilities of the sharing framework, it may have the further positive effect of encouraging the incumbent users to make more efficient use of the spectrum resource (and possible sharing with federal incumbent users in other bands) allowing broader (and possibly additional) ASA rights to be auctioned and thus possibly raise more money for the U.S. Treasury.

As should be clear from the above discussion, ASA does not involve a new air interface or any less reliable form of communications as compared to today's mobile broadband technologies. And, Qualcomm is not asking the Commission to mandate any air interface or technology. Rather, ASA licensees would use a mobile broadband air interface and, in fact, could deploy macrocells (in areas outside NTIA's original exclusion zones for example) and small cells, depending on the restrictions imposed to accommodate incumbents at a given location, point in time, and frequency. As noted above, if the 3.5 GHz band is made available using ASA, the band can be used to enable carrier aggregation or supplemental downlink in conjunction with bands already supported on existing mobile broadband networks to achieve the best possible user experience.

C. <u>The Commission Should Leverage The ASA Standardization Efforts In ETSI</u>

There are active efforts in the European Telecommunications Standards Institute ("ETSI") to standardize ASA. In fact, ASA has been endorsed by 27 European Union member states. The FCC should closely review and, where possible, leverage these European efforts.

Since May 2012, the ETSI Technical Committee Reconfigurable Radio Systems ("TC RRS") has been working towards standardizing the use of ASA. In Europe, ASA is known as Licensed Shared Access ("LSA") — ASA and LSA are one and the same. ETSI is standardizing ASA/LSA to enable mobile broadband services at 2.3-2.4 GHz. The 2.3 GHz band is allocated to the mobile service in Europe and globally in the ITU Radio Regulations. As is the case with the FCC's *3.5 GHz Small Cells NPRM*, ASA/LSA is being implemented in Europe to enable mobile broadband services in those European Conference of Post and Telecommunications Administrations ("CEPT") countries where the band is currently occupied by other incumbent users.[16] And, like the 3.5 GHz band primary incumbents in the U.S., the incumbent users at 2.3 GHz in Europe are "holders of spectrum rights of use that have not been granted through an award procedure [] for commercial use."[17]

In ETSI, the standardization work is being carried out in several distinct steps. The first step, which is almost complete, is the drafting of a Technical Report called a "System Reference Document (SRdoc)" that defines the criteria and operational features for ASA/LSA at 2.3 GHz and thus supports the cooperation between ETSI and the Electronic Communications Committee (ECC) of the CEPT.[18] This Technical Report will be used within the relevant CEPT Working Groups and Project Teams, in particular, to aid in necessary studies to enable the harmonized use of the 2.3 GHz frequency band in the EU.

The Report addresses regulatory issues, market information, as well as technical information including spectrum compatibility issues, among other items. While this Technical Report focuses on the 2.3 GHz band and pan-European applications, there is no reason why the

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16 For example, in Europe the French and Swiss military operate radar systems in the 2.3 GHz band.

17 *See* DIGITALEUROPE *Position Paper on Licensed Shared Access (LSA) Common Understanding, Status and Next Steps* (Feb. 14, 2013) (note preceding hyperlink to Position Paper, *last accessed* Feb. 20, 2013). DIGITALEUROPE members include the world's largest IT, telecoms and consumer electronics companies (60 global corporations) and more than thirty national associations from every part of Europe.

18 *See* ETSI Technical Report, TR 103 113 (2013-02) *Reconfigurable Radio Systems (RRS); System Reference Document; Mobile Broadband Services in the 2300 MHz – 2400 MHz Frequency Band under Licensed Shared Access Regime*.

underlying concepts could not also be applied to other frequency bands and regions, including the 3.5 GHz band in the U.S.

In a next step, ETSI TC RRS will begin developing the relevant Technical Specifications for mobile broadband service at 2.3 GHz using ASA/LSA, taking into account the regulations developed by CEPT for this band. This will be performed in several stages as follows:

- Stage 1: Development of a Technical Specification ("TS") with requirements including:
    - Definition of technical and non-technical aspects required for the operation of mobile broadband networks at 2.3 GHz under an ASA/LSA framework; these requirements will be defined in cooperation with incumbent users, relevant regulatory authorities, mobile network operators, as well as equipment and device manufacturers.
- Stage 2: Development of a TS on functional architecture including:
    - Definition of different logical entities and their respective functionalities;
    - Definition of interfaces between the standardized logical entities and the external entities.
- Stage 3: Development of a TS on protocols, security models and data content including:
    - Specifications for protocol details of the interfaces such as request/response models, push/pull mechanisms, underlying transport and network models, security procedures, etc.;
    - Detail of the information elements carried on the interfaces.
- Conformance testing and certification
    - Test methodologies for the interfaces, certification of terminals.

As noted above, the FCC should monitor the progress of ASA/LSA in Europe (and elsewhere) and leverage this work as appropriate, for it can help speed the deployment in this country of small cell technology using ASA at 3.5 GHz.

D. <u>There Are Key Differences Between The ASA Regulatory Framework And The FCC's TV White Space Rules</u>

Qualcomm would like to point out several important differences between the ASA framework and the Commission's TV White Space regulatory framework.[19] In contrast to

[19] *See, e.g.,* 47 C.F.R. §§ 15.701 to 15.717.

sharing in an unlicensed regulatory framework where multiple uncoordinated users are permitted access the same frequency band at the same location and at the same time, licensed ASA technology enables a licensed network operator to tightly manage access to the ASA spectrum, as explained above, in order to provide all users with a reliable quality of service, with all the proven interference management/mitigation/cancellation techniques available in today's licensed mobile broadband technology. ASA, along with licensed operation, provides the command and control structure necessary to utilize and vacate spectrum as needed by government incumbent users; no "rogue" devices can operate in such a framework. Thus, Qualcomm agrees with the Commission that licensed status provides "greater interference protection status in the Table of Frequency Allocations" and "a more unified authorization framework,"[20] and, hence, is better suited to support the FCC's goals in the *3.5 GHz Small Cells NPRM.* While unlicensed spectrum, such as the 2.4 GHz and 5 GHz Wi-Fi bands, are well suited for short range, non-overlapping, best-efforts performance, unlicensed bands cannot ubiquitously support the predictable quality of service that today's mobile broadband services and applications require as the FCC recognizes.

As noted above, ASA gives spectrum use rights to a discrete, identifiable group of operators, as compared to a disparate group of unspecified and unlicensed users. As a result, ASA can fully protect incumbents, and if there are problems with interference caused by sharing, the ASA licensee is readily identifiable. And, unlike unlicensed operations, because ASA can support a secondary licensed mobile broadband operator and provide a predictable quality of service, the Commission can auction ASA spectrum rights to allow operators to gain access to under-utilized spectrum.

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[20] *See 3.5 GHz Small Cells NPRM* at ¶ 11.

Finally, the information that federal incumbent users will be providing in order to enable sharing with mobile broadband use is sensitive information, potentially highly classified information in the case of military radar systems, so it is particularly important that such information be kept secure. The ASA regulatory framework, which provides a secure connection to an operator's OAM system, is particularly well-suited for these purposes.[21]

II. <u>ASA-Enabled Small Cells Can Support A Mobile Broadband Quality Of Service While Successfully Sharing Spectrum With Primary Users</u>

Qualcomm agrees with the FCC that the 3.5 GHz holds "great promise for small cell applications" and that the radio propagation characteristics can facilitate "dense deployment of small cells with a reduced risk of harmful interference to geographically or spectrally adjacent users" and thus tremendously increase network capacity through intensive frequency reuse.[22] Indeed, dedicating a band for small cell use exclusively will avoid interference issues that exist when macro cells and small cells are deployed within the same band.

The FCC also rightly notes that these same characteristics make the band well-suited for "spectrum sharing, particularly geographic sharing" for it can "allow disparate radio systems to operate in closer proximity than lower frequency bands," and thus not only support enhanced sharing with incumbent users, but also enable greater sharing with potentially disparate commercial systems in the band.[23] As Qualcomm has explained above, the exclusive right to use the spectrum may be awarded by geographic area (similar to licenses awarded today via auction), or via a licensed-by-rule framework, or perhaps both, each in discrete portions of the bands. For geographic area licensing, the FCC could auction channels in areas across the U.S. as it does

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[21] In contrast, the TV White Space database uses information that is publicly available on the FCC's website, namely the location and power levels of TV stations.

[22] *See 3.5 GHz Small Cells NPRM* at ¶ 20.

[23] *See id.* at ¶ 21.

with traditional mobile licenses, and allow the auction winners to deploy small cells using ASA within the exclusion zones and possibly deploy macro-cells in areas well inland, outside the exclusion zones originally identified by NTIA.

Should the FCC decide to implement a licensed-by-rule regime in certain portions of the band, it could, for example, allow consumers and enterprises to install small cells to provide service within and around their residences/businesses. In either case, Qualcomm believes that the options for licensing the band for use by small cells require further examination as more detailed information about the incumbent operations becomes available.

With regard to a band plan, Qualcomm suggests that the 3.5 GHz band use 20 MHz-wide channels and that, because of unique factors arising from the presence of government incumbents, TDD ("Time-Division-Duplex") technology would be preferred for this band. In contrast to a FDD plan, a TDD plan in this band will better support continued full duplex communications if a small cell is required to move to an open channel in order to avoid receiving interference from (or causing interference to) incumbent government users. Also, a TDD plan would avoid the need for complicated guard bands, since guard bands would not necessarily coincide with the frequencies that the government incumbents use.[24]

A. Deployment Of Small Cells At 3.5 GHz Reduces By An Order Of Magnitude The Exclusion Zones Originally Identified By NTIA

In the *3.5 GHz Small Cells NPRM*, the Commission estimates that the original exclusion zones proposed by NTIA, which were based on the deployment of macro-cells, covered approximately 60% of the U.S. population.[25] The FCC properly recognizes in the *NPRM* that the deployment of small cells, when used in conjunction with ASA technology, will also allow the

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24 *See 3.5 GHz Small Cells NPRM* at ¶ 74 (seeking input on a 3.5 GHz band plan, including the size of channels).

25 *See id.* at ¶ 6.

exclusion zones needed for co-existence with Naval radars to be shrunk substantially as compared to the several hundred mile inland exclusion zones originally envisioned by NTIA.[26] This is exactly what Qualcomm has found, as explained below.

The NTIA Fast Track Report assumed that the band would be used by macro cells transmitting at 46 dBm or 40 W and be coupled to an antenna with a 14 dBi gain.[27] NTIA determined that large geographic exclusion zones would be necessary for shipborne radars, reaching a maximum of 557 kilometers inland from one type of shipborne radar into a base station located in the Gulf Coast region.[28]

Qualcomm's re-calculations, which use the NTIA model but with operating parameters appropriate for small cells, show that these exclusion zones can be dramatically reduced. As detailed in the Appendix to these Comments, Qualcomm analyzed the deployment of small cells in the coastal area of San Diego and showed that the exclusion zone can be reduced to less than 10 miles for the case of a small cell causing interference to a shipborne radar system. Qualcomm's calculations demonstrate that, so long as the product of the small cell density and the small cell transmit power remain constant, increasing the densification of small cells will not increase the level of interference to shipborne radar systems. And importantly, as explained in the following section of these Comments, increasing the network densification dramatically increases the network capacity.

With regard to on-channel interference from a radar system into a small cell, based on the information available in the NTIA Fast Track Report regarding the radar systems, there is little protection within the exclusion zones, and Qualcomm recommends that the ASA framework be

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26 *See id*.

27 *See also id.* at ¶ 115.

28 *See id.*

used to control when and where small cells can operate within the exclusion zones. Additional information on the characteristics of the radar signals is needed to determine the extent to which small cell operations can occur within other portions of the 3.5 GHz band when the radar systems are transmitting. Qualcomm is pleased that the federal government is in the process of providing additional information on the characteristics of radar signals.

B. Small Cells Enable Greater Spectrum Reuse And Tremendous Capacity Gains

Qualcomm has found that the deployment of small cells will deliver tremendous capacity gains through LTE heterogeneous network techniques in conjunction with interference mitigation and cancellation at the devices. Thus, the deployment of small cells will provide a much better experience for the users served via macrocells and the users served via small cells. As shown in the Appendix to these Comments, network densification with small cells can increase network capacity by 100 times, even where the transmit power for each small cell is as low as 13 dBm.[29]

By using a dedicated band for small cells, there is no need for additional interference management between macrocells, picocells and femtocells sharing the same spectrum, for there is no need to share spectrum with the macrocellular network. In this way, small cells would readily "extend wireless coverage to areas where macro cell signals are weak" and "provide additional data capacity in areas" where existing macro cells may be overloaded.[30]

Small cells can also take advantage of the many other interference mitigation techniques and network reliability tools — which are not generally implemented in today's unlicensed

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[29] While Qualcomm analyzed the potential use of TDD LTE-based small cells within the 3.5 GHz band, the FCC should not mandate the use of LTE or, for that matter, any air interface at 3.5 GHz.

[30] *See 3.5 GHz Small Cells NPRM* at ¶ 30.

devices[31] — but are integral to mobile broadband networks operating on licensed spectrum (and using LTE). These techniques and tools include: (i) both open and closed loop power control, which ensures that the small cells and connected devices transmit at the optimum power level to ensure successful communications and minimize interference to other users; (ii) inter-cell interference management; (iii) interference cancellation within devices; (iv) self organizing networks, where small cells are able to expand and contract their coverage areas as needed to avoid interfering with one another (like today's macrocells); (v) plug-and-play operation where new cells are instantly recognized and incorporated into the carrier's network; and (vi) instant mobility with fallback to carrier networks where small cell connectivity is not available. Indeed, by establishing 3.5 GHz as a licensed band, the mobile broadband service on the band will have far more capacity and will be far more reliable than what can be achieved today via simple Wi-Fi off loading.

C. <u>The FCC Should Add The 3650 to 3700 MHz Band For Small Cell Use</u>

Qualcomm believes that the Commission should include the 3650-3700 MHz band as part of the 3.5 GHz small cell band.[32] The current users in the 3650-3700 MHz band could be incorporated into the ASA database to ensure that small cells operate on an interference-free basis within this highly useful additional 50 MHz swath of spectrum.[33] Given that there are only 2,117 registered licensees and roughly 25,000 registered sites in the 3650-3700 MHz band, there is plenty of open space in the geography/time/frequency realms in which to allow small cells to

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31 It "is not uncommon to see as many as 25 different Wi-Fi networks operated from a single location," *id*. at ¶ 33, which are generally uncoordinated and thus result in inefficient spectrum use.

32 *See 3.5 GHz Small Cells NPRM* at ¶ 28.

33 The NPRM explains that operations in the 3650-3700 MHz band are authorized through non-exclusive nationwide licenses and requires the registration of individual fixed and base stations that employ a contention-based protocol. *See 3.5 GHz Small Cells NPRM* at ¶ 28.

operate and thus provide added mobile broadband capacity.[34] Indeed, as the FCC notes in the *NPRM*, the number of actual sites is substantially less because registered sites reflect single sectors of a base station, which means that all multi-sector base stations are represented by more than one co-located registration.[35]

III. Qualcomm Looks Forward To Continuing To Work With The FCC, NTIA and Other Interested Stakeholders Towards Enabling Small Cell Deployments At 3.5 GHz

As these Comments indicate, Qualcomm is very excited about the deployment of small cells at 3.5 GHz enabled via the ASA regulatory framework. As the Commission well knows, Qualcomm has been working on both ASA and small cells for years. However, in order for these innovations to become reality at 3550 to 3700 MHz, additional information about the extent and level of federal radar use is needed. Qualcomm is pleased that efforts are underway within the federal government to collect and share that information, for it is an essential ingredient for further refining our technical analysis and associated calculations.

Qualcomm's calculations of the likely reduction in exclusion zones using small cells in place of macro cells included assumptions of various technical data that would need to be verified and then possibly re-calculated in order to reflect the more realistic scenarios. Given the foundational engineering analyses that Qualcomm has engaged in to date, any such refinement to the calculations would be straightforward and thus can be completed expeditiously.

[34] *See 3.5 GHz Small Cells NPRM* at ¶ 77. Base and fixed stations can operate with 25 W EIRP per 25 MHz with 1W peak EIRP/MHz density; mobile and portable stations are limited to 1 W EIRP per 25 MHz and 40 mW peak EIRP/MHz density. *See id*. at ¶ 28.

[35] *See id*. at ¶ 77.

CONCLUSION

Qualcomm is pleased to provide the foregoing comments on the *Small Cells NPRM*. As the FCC well knows, mobile broadband spectrum is the lifeblood of today's information economy and America's economic success, for such spectrum is essential to enabling "a high-performance America — a more productive, creative, efficient America in which affordable broadband is available everywhere and everyone has the means and skills to use valuable broadband applications."[36] We look forward to continuing to work with the Commission and our industry partners towards the timely deployment of small cells in the 3.5 GHz band to support mobile broadband operations and continue to fuel our remarkable mobile broadband ecosystem.

Respectfully submitted,

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Dated: February 20, 2013

[36] FCC National Broadband Plan (Mar. 16, 2010) at 9.

APPENDIX

Technical Parameters and Calculations of the Reduced Exclusion Zones and Increased System Capacity By Deploying Small Cells in the 3.5 GHz Band

In this Appendix, Qualcomm provides the technical details associated with the calculations of: (i) the reduced exclusion zones where small cells are deployed within the exclusion zones originally identified in the NTIA Fast Track Report, and (ii) the increased system capacity calculations for such small cell deployments — both of which are described in Section II of the foregoing Comments of Qualcomm Inc. This analysis used pathloss models (*i.e.*, the Irregular Terrain Model ("ITM")) that is similar to the models that NTIA used in the Fast Track Report. The relevant ITM parameters are provided in Table A.1 below.

Parameter	Notation	Value
Carrier Frequency	F	3.6 GHz
Antenna polarization code	$ipol$	1 - vertical
Conductivity of the ground	σ	0.005 S/m
Relative Permittivity (dielectric constant)	ϵ_r	15.0
Surface Refractivity in N-units	N_s	301
Climate code	$klim$	5 - continental temperate
Siting criteria	kst	0 - random siting
Time variability quantile	q_T	0.5
Location variability quantile	q_L	0.5
Situation variability quantile	q_S	0.5

Table A.1. Irregular Terrain Model Parameters

Interference Analysis

Nomenclature

eNB = Small cell base station

UE = User Equipment

Interference scenarios considered
LTE eNB Transmissions ("Tx") into the Incumbent (radar) Receivers ("Rx")
LTE UE Tx into Incumbent (radar) Rx

Qualcomm's interference analysis used the following values for the noted parameters:

Parameter	Value	Note
Small cell power	23 dBm	Also used 10, 13, 16, 30 dBm
Small cell Tx BW	20 MHz	
Small cell antenna gain	5 dBi	Omnidirectional antenna
Small cell antenna height	3 m	
Macro cell power	46 dBm	
Macro cell Tx BW	20 MHz	
Macro cell antenna gain	17 dBi	Three sector antenna
Macro cell antenna height	30 m	
Frequency	3.5 GHz	
Radar antenna gain	Variable	Details below
Radar antenna height	30 m	
Penetration loss	20 dB	
Pathloss		Irregular Terrain Model (shown below)

Table A.2. Various Parameters and Values Used in the analysis

Example path loss values as function of transmitter-to-receiver distance are shown in Figure A.1 below.

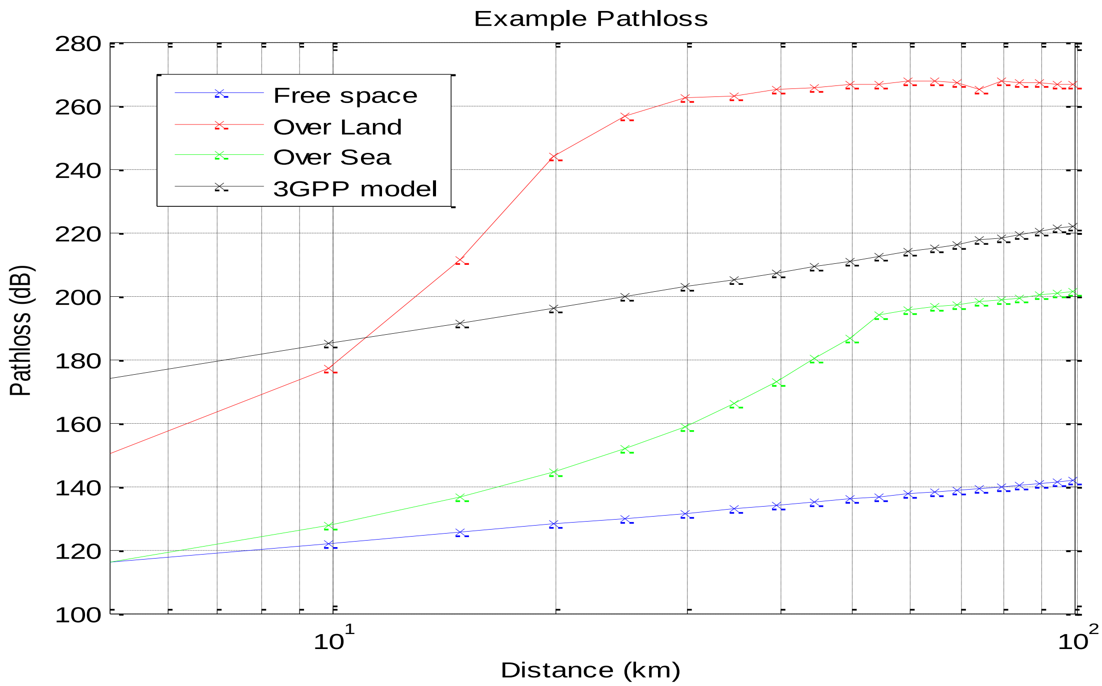

Figure A.1. Sample Pathloss as a Function of Distance

The 3GPP model depicted in Figure A.1 is based on the following equation:

$$PL = 36.7 \cdot \log_{10}(d) + 26 \cdot \log_{10}(f_c) + 22.7$$

This model comes from *3GPP 36.814 v9.0.0, Further advancements for E-UTRA physical layer aspects*, (March 2010), B.1.2.1. Note also that for distances less than 6 km, the difference between the 3GPP model and the over land pathloss is greater than 20 dB. The "over land" plot stretches from the San Diego coast to up to 100 km eastward inland. The "over sea" plot is from the coast stretching 100 km west over the Pacific

The deployment models used in this analysis are shown in Figures A.2 and A.3. Figure A.2 shows the total area of cellular coverage of deployed eNBs and the exclusion zone. Figure A.3 shows the deployed small cells within the coverage area; 5,296 small cells are depicted.

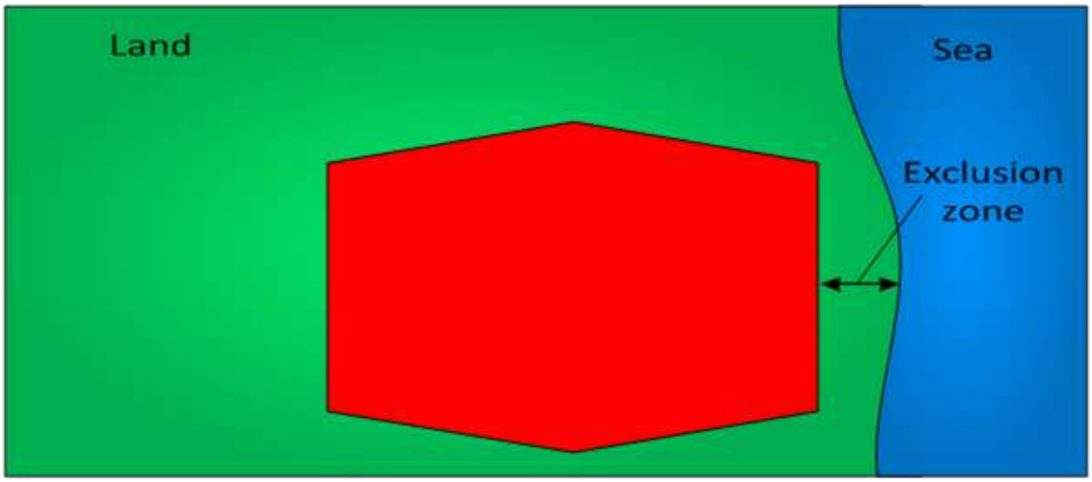

Figure A.2. Macrocell – Hexagonal, 500 m (site-to-site), 10 tiers

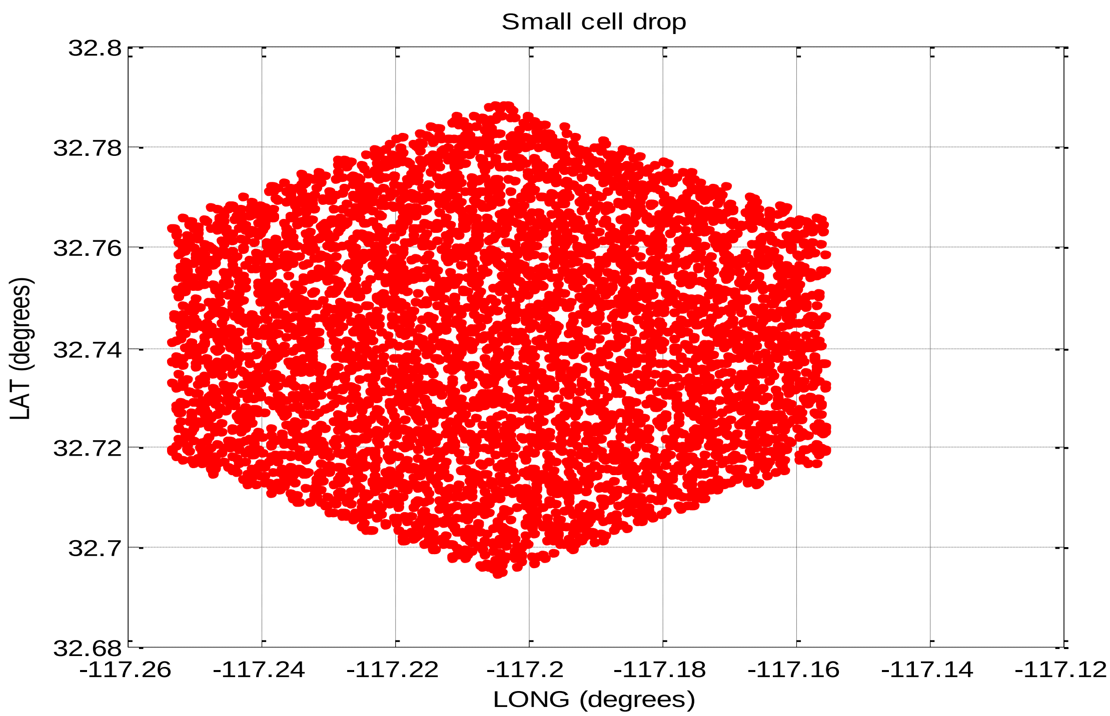

Figure A.3. Small Cell Drop – Randomly within macrocell footprint

The analysis assumed that either the macrocell or a collection of small cells was operational within the macrocell footprint at a given point in time. Note that the case of macro cells operating at 3.5 GHz is only shown as reference. Collections of 200, 1000, 5296, and 52960 small cells were analyzed, with 0.6, 3, 16 or 160 small cells active within the footprint of a particular macrocell. Note that in the case of small cells operating in 3.5 GHz, only the assumed footprint of the macro cells are utilized since the macro cells in this case themselves operate in another band below 3.5 GHz.

The simulated location for the analysis was placed at the following latitude/longitude location: 32°44’30.0”N; 117°15’20.0”W. Two map views of this location are shown below:

The permissible interference levels for each of the analyzed radar systems are provided in Table A.3 below. Qualcomm assumed that the ship is located 10 km off shore.

Radar Type	N_o (dBm)	IoT (dB)	Allowed Interference (dBm)	Antenna Gain (dBi)	ACLR (dB)
Ground-based type 1	-103	-6	-109	16	40
Ground-based type 2	-100	15	-85	8	40
Ground-based type 3	-96	-6	-102	39.7	40
Airborne type 1	-92.5	30	-62.5	17	40
Airborne type 2	-100	40	-60	17	40
Shipborne type 1	-108	-6	-114	32	0
Shipborne type 2	-95	-6	-101	47	40
Shipborne type 3	-94	-6	-100	41.8	40
Shipborne type 4	N/A	N/A	-114 (estimated)	38.9	0
Shipborne type 5	N/A	N/A	-114 (estimated)	43.3	0

Table A.3. Permissible Interference Levels

The antenna patterns for each type of radar systems that was analyzed are provided in Table A.4 below.

Radar Type	Antenna Gain (dBi)	(degrees)
Ground-based type 1	16	82
Ground-based type 2	8	N/A
Ground-based type 3	39.7	0.35
Airborne type 1	17	65 (N/A)
Airborne type 2	17	65 (N/A)
Shipborne type 1	32	2.1
Shipborne type 2	47	0.065
Shipborne type 3	41.8	0.22
Shipborne type 4	38.9	0.42
Shipborne type 5	43.3	0.15

Table A.4. Radar Antenna Patterns

The size of the exclusion zone versus small cell density is provided in Table A.5 below.

Radar Type	Frequency	5296 cell Exclusion zone (km)	200 cells Exclusion zone (km)	200 cells outdoor Exclusion zone (km)	331 cells outdoor macro Exclusion zone (km)
Ground type 1	Off-channel	0.9	0	4	15
Ground type 2	Off-channel	0	0	0	4.5
Ground type 3	Off-channel	0.3	0	1	9
Airborne type 1	Off-channel	0	0	0	0
Airborne type 2	Off-channel	0	0	0	0
Shipborne type 1	On-channel	14.5	9	18	51
Shipborne type 2	Off-channel	0	0	0	19
Shipborne type 3	Off-channel	0	0	0	19
Shipborne type 4	On-channel	14	9	17	51
Shipborne type 5	On-channel	14.5	9	17	51

Table A.5. Size of Exclusion Zone vs. Cell Density

The size of the exclusion zone versus the small cell transmit power is provided in Table A.6 below. This table shows that the exclusion zone is as little as 9.5 km from the coastline when 5296 small cells operating at 10 dBm are deployed.

Radar Type	Frequency	5296 cell 23 dBm Exclusion zone (km)	5296 cell 16 dBm Exclusion zone (km)	5296 cell 10 dBm Exclusion zone (km)
Ground-based type 1	Off-channel	0.9	0.2	0
Ground-based type 2	Off-channel	0	0	0
Ground-based type 3	Off-channel	0.3	0	0
Airborne type 1	Off-channel	0	0	0
Airborne type 2	Off-channel	0	0	0
Shipborne type 1	On-channel	14.5	11	9.5
Shipborne type 2	Off-channel	0	0	0
Shipborne type 3	Off-channel	0	0	0
Shipborne type 4	On-channel	14	11	9.5
Shipborne type 5	On-channel	14.5	11	9.5

Table A.6. Size of Exclusion Zone vs. Small Cell Transmit Power

Finally, Table A.7 below shows results where the number of small cells, within a deployment of a given size, is set inversely proportional to the small cell transmit power. Table A.7 shows that the size of the exclusion zones is invariant while the number of small cells is inversely proportional to the (linear) transmit power, where the product of the small cell density and the small cell transmit power remain constant. The below Table also shows that the size of the exclusion zones in all of these cases is drastically reduced by deploying small cells in the 3.5 GHz band, to less than 15 km inland (as shown below in red text) for shipborne radar systems, which are operating 10 km off-shore.

Radar Type	Frequency	5296 cell 23 dBm Exclusion zone (km)	52960 cell 13 dBm Exclusion zone (km)	1000 cell 30 dBm Exclusion zone (km)
Ground-based type 1	Off-channel	0.9	0.9	0.9
Ground-based type 2	Off-channel	0	0	0
Ground-based type 3	Off-channel	0.3	0.3	0.3
Airborne type 1	Off-channel	0	0	0

Airborne type 2	Off-channel	0	0	0
Shipborne type 1	On-channel	14.5	14.5	14.5
Shipborne type 2	Off-channel	0	0	0
Shipborne type 3	Off-channel	0	0	0
Shipborne type 4	On-channel	14	14	14
Shipborne type 5	On-channel	14.5	14.5	14.5

Table A.7. Size of Exclusion Zone vs. Small Cell Density and Transmit Power

This analysis demonstrates that the resulting exclusion zones when LTE-based small cells are deployed can be dramatically reduced to less than 10 miles inland and still protect incumbent radar systems. Moreover, increased densification of LTE-based small cells does not increase the interference to radar systems at 3.5 GHz so long as the product of the small cell density and the small cell transmit power remains constant.

Thus, this analysis shows that small cells should be deployed within the exclusion zones identified in the NTIA Fast Track Report. Macro cells may be deployed outside the originally identified exclusion zones.

On-channel interference from radar systems to LTE-based small cells may still occur. Therefore, ASA should be employed to enable small cell operations within the exclusion zone areas originally identified in the NTIA Fast Track Report.

LTE-based Small Cell Network Capacity Simulation

Qualcomm's small cell network capacity simulations included the assumptions shown in Table A.8 and depicted in Figure A.4. Small cells were randomly dropped in an apartment building statistically independent of other small cell locations, and at most one small cell was dropped in any one apartment.

The simulation leverages the "dual-stripe" dense urban model available in 3GPP with some modifications, as explained below. There are multi-floor apartment blocks, and each floor has 10 apartments, with 2 rows and 5 apartments per row, as shown in Figures A.4 and A.5.

The RF propagation modeling assumes indoor multi-wall and floor losses as follows: Wall loss = 5 dB (internal) and 20 dB (external); floor loss = 18.3 dB. Lognormal shadowing is used with standard deviation = 4 dB (same apt) or 8 dB, with 8 dB additional path loss at 3.5 GHz. Finally, the transmit power was 23 dBm or 13 dBm, as indicated.

Parameter	Value
Macrocell ISD	500m
Population Density	20000 per sq km
Number of Apartments per Macrocell (2 subs per Apt.)	720
User Distribution	70% Indoors/30% Outdoors; Randomly dropped

Table A.8. Parameters Used In Small Cell Network Capacity Analysis

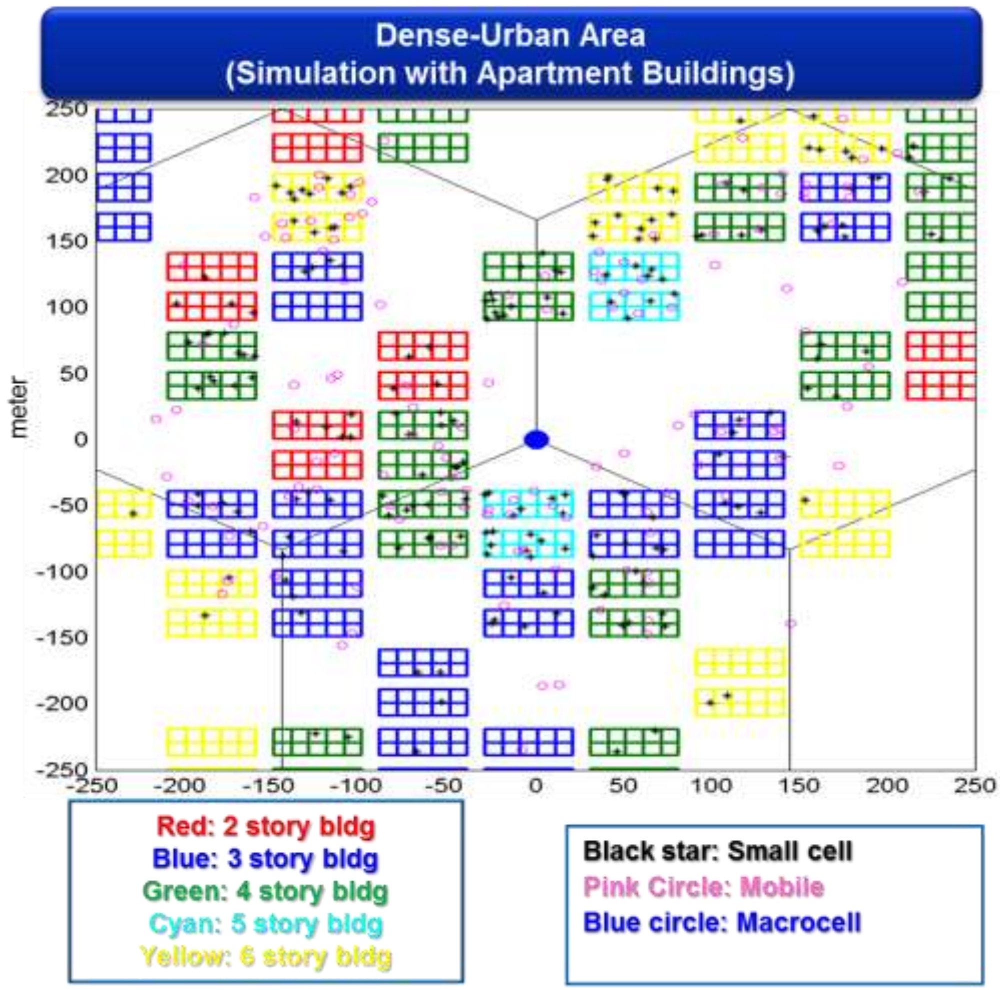

Figure A.4. Dense Urban Area Model Used for Simulation

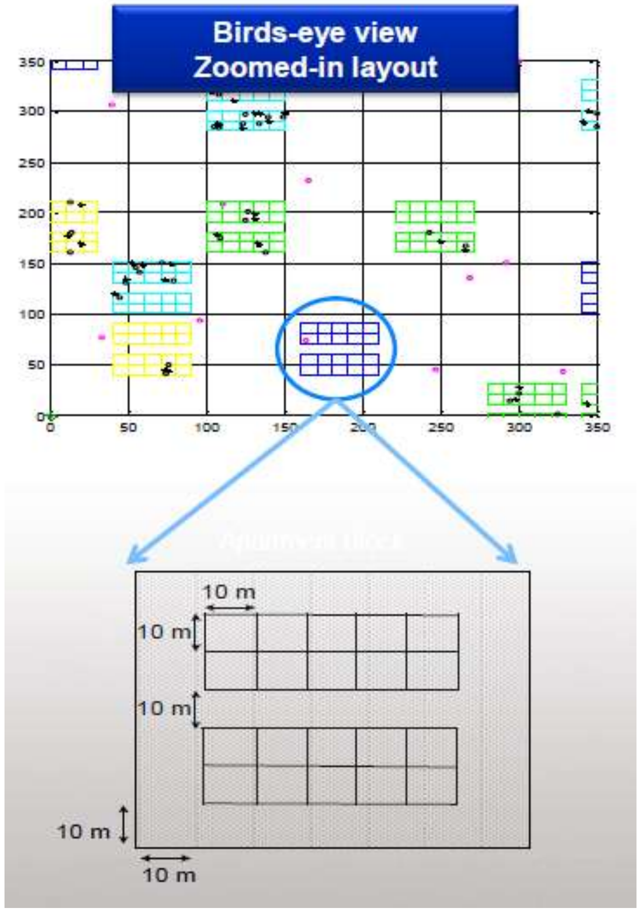

Figure A.5. Bird's-eye View, Zoomed In Layout

The results of the simulation are provided in Table A.9 below. The highlighted rows indicate cases where the product of the small cell density and the small cell transmit power is constant. They show that with the same exclusion zone, there is a great capacity increase (up to 100x) when the number of small cells deployed increases from 16 to 160 and the transmit power level is reduced by 10 dB to 13 dBm, while the effect on radars remains the same.

Deployment Model (200 UEs / Macrocell)	Median Throughput Gain (relative to macro-only baseline)	Tail (5%) Throughput Gain (relative to macro-only baseline)
16 SCs, SC Tx Pwr = 23 dBm	8.8x	3.3x
16 SCs, SC Tx Pwr = 13 dBm	4.6x	2.2x
160 SCs, SC Tx Pwr = 23 dBm	106.5x	39x
160 SCs, SC Tx Pwr = 13 dBm	100.2x	33.5x

Table A.9. Simulation Results with 200 UEs per Macrocell

Conclusion

The deployment of LTE-based small cells allows the exclusion zones originally identified in the NTIA Fast Track Report to be substantially reduced, while network capacity can increase 100 times when a manageable number of small cells are deployed.

In addition, increasing small cell density does not increase interference to radar as long as the small cell transmit power is reduced proportionally. At the same time, densification increases LTE network capacity — over 10 times more capacity becomes available when density increases 10 times and small cell transmit power is reduced by 10 dB. To reiterate, this analysis shows that substantial capacity gains can be achieved without any increased interference to radar systems.

References

The following references were used in these analyses:

1. *An Assessment of the Near-Term Viability of Accommodating Wireless Broadband Systems in the 1675-1710 MHz, 1755-1780 MHz, 3500-3650 MHz, and 4200-4220 MHz, 4380-4400 MHz Bands,* U.S. Department of Commerce.

2. *Spectrum Occupancy Measurements of 3550-3650 MHz Maritime Radar Band Near San Diego, CA*, NIST (July 2012).

3. *3GPP 36.814 v9.0.0, Further advancements for E-UTRA physical layer aspects* (Mar. 2010).